

Seasonal Changes in Concentrations of Dissolved Pesticides and Organic Carbon in the Sacramento–San Joaquin Delta, California, 1994–1996

Prepared in cooperation with California Bay–Delta Authority

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Inside front cover

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by James L. Orlando and Kathryn M. Kuivila

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Abbreviations and Acronyms

Delta, Sacramento–San Joaquin Delta
 DOC, dissolved organic carbon
 GC/MS, gas chromatography/mass spectrometry
 in., inch
 in./day, inch per day
 L, liter
 μm , micrometer
 mg/L, milligram per liter
 mL, milliliter
 mm, millimeter
 ng/L, nanogram per liter
 NWIS, National Water Information System
 TMDL, Total Maximum Daily Load
 USGS, U.S. Geological Survey
 Acronyms
 NWIS, National Water Information System

Datum: Vertical coordinate information is referenced to the North American Vertical Datum of 1988 (NAVD 88). Horizontal coordinate information is referenced to the North American Datum of 1983 (NAD 83). Altitude, as used in this report, refers to distance above the vertical datum.

Temperature in degrees Celsius ($^{\circ}\text{C}$) may be converted to degrees Fahrenheit ($^{\circ}\text{F}$) as follows:

$$^{\circ}\text{F} = (1.8 \times ^{\circ}\text{C}) + 32$$

Temperature in degrees Fahrenheit ($^{\circ}\text{F}$) may be converted to degrees Celsius ($^{\circ}\text{C}$) as follows:

$$^{\circ}\text{C} = (^{\circ}\text{F} - 32)/1.8.$$

Specific conductance is given in microsiemens per centimeter at 25 degrees Celsius ($\mu\text{S}/\text{cm}$ at 25°C)

NOTE TO USGS USERS: Use of liter (L) as a special name for cubic decimeter (dm^3) is restricted to the measurement of liquids and gases. No prefix other than milli should be used with liter.

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Seasonal Changes in Concentrations of Dissolved Pesticides and Organic Carbon in the Sacramento–San Joaquin Delta, California, 1994–1996

By James L. Orlando and Kathryn M. Kuivila

Abstract

The Sacramento–San Joaquin Delta (Delta) of California is an ecologically rich and hydrologically complex region that receives runoff from nearly one-quarter of the state. Water-quality studies of surface water in the region have found dissolved pesticides in winter storm runoff at concentrations toxic to some aquatic invertebrates. However, scientists have little information on pesticide concentrations in the Delta on a seasonal timescale or the importance of pesticide contributions from within-Delta sources. Consequently, the U.S. Geological Survey conducted a study from 1994 to 1996 during which water samples were collected seasonally from 31 sites located within the Delta and on major tributaries to the Delta. Water samples were analyzed for 20 current-use pesticides and dissolved organic carbon. During the study, 11 current-use pesticides were detected; maximum concentrations ranging from 17 ng/L (for trifluralin) to 1,160 ng/L (for metolachlor). The highest concentrations of five pesticides (carbaryl, carbofuran, metolachlor, molinate, and simazine) were greater than 900 ng/L. The greatest number of pesticides was detected in the summer of 1994, whereas the least number were detected in the winter of 1994. The herbicides metolachlor and simazine were the most frequently detected pesticides and were detected in five of the six sampling seasons. The herbicides molinate and EPTC were detected only during the three summer sampling seasons. A comparison of pesticides detected during the spring and summer of 1995 showed some seasonal variability. Comparison of the three summer seasons sampled showed that a larger number of pesticides were detected, and with generally higher maximum concentrations, in 1994 than in 1995 or 1996. Dissolved organic carbon (DOC) concentrations ranged, over the course of the study, from 1.4 mg/L to 10.4 mg/L, and had a median concentration of 3.8 mg/L. On a seasonal basis, the lowest maximum DOC concentrations occurred during the summer and winter of 1994. The highest median DOC concentration on a seasonal basis occurred in the spring of 1995. This previously unreported data is being published now to provide historical information on pesticide concentrations in the Delta to water managers and the scientific community.

Introduction

The Sacramento–San Joaquin Delta (Delta) is a hydrologically complex region within the Central Valley of California comprised of interconnecting sloughs and channels and containing numerous leveed and farmed islands. The Delta is fed by two major river systems, the Sacramento and the San Joaquin as well as by a number of smaller tributaries. The Delta is a highly productive area both ecologically and economically, and is a major source of drinking water for much of California.

In total, the Delta receives runoff from a watershed of nearly 25 million acres. Over five million acres within the watershed are devoted primarily to agriculture and the production of a wide variety of crops. The region also contains numerous urban centers of varying size with a combined area of over half a million acres. During the period of this study, 1994 through 1996, an average of slightly over 55 million pounds of pesticide active ingredient were applied annually in the watershed (California Department of Pesticide Regulation, 2005).

In the Central Valley and Delta, studies have shown that the first significant rainfall (greater than 0.5 in./day) and subsequent runoff following the winter application of dormant spray pesticides is accompanied by a rise in the detected concentrations of these same pesticides in downstream surface waters (Kuivila and Foe, 1995; Kratzer, 1997; Orlando and others, 2003 and 2004). Studies have also shown these pulses of multiple pesticides to be acutely toxic to the aquatic invertebrate *Ceriodaphnia dubia* (Foe and Connor, 1991, Kuivila and Foe, 1995). However, scientists have little information on the seasonal variation in pesticide concentrations within the Delta or the influence of local, within-Delta, sources of pesticides.

In addition, the toxicity of pesticides to aquatic species is influenced by a variety of environmental factors in natural waters, such as dissolved organic matter (Haitzer and others, 1998). Dissolved organic matter is most commonly quantified in terms of dissolved organic carbon (DOC). The concentration and type of dissolved organic matter can influence the toxicity of a contaminant by increasing or decreasing its bioavailability to aquatic species (Kukkonen and Oikari, 1987; Benson and Long, 1991; Day, 1991; Kadlec and Benson, 1995). It is

therefore valuable to measure DOC concentrations when trying to relate pesticide concentrations in natural waters to observed toxicity.

Very little historical information on pesticide concentrations in Delta waterways is available. Data from this study has not been previously published, and is being published now in an effort to augment the historical record. These data will prove useful to water managers and the scientific community in the proposed establishment of Total Maximum Daily Load (TMDL) requirements for the Delta. These data are presented at a time of increased concern over recent declines in fish populations in the region.

Project Design

This project was designed to provide information on the seasonal occurrence and concentrations of current-use pesticides and DOC in surface waters within the Delta and to examine the contribution of pesticides from within-Delta sources. Water samples were collected from 31 sites located in the central Delta and from the major tributaries of the Delta (fig. 1). Samples were analyzed for dissolved pesticides, DOC, and other water-quality parameters (temperature, pH, and specific conductance). Sites were sampled quarterly, beginning

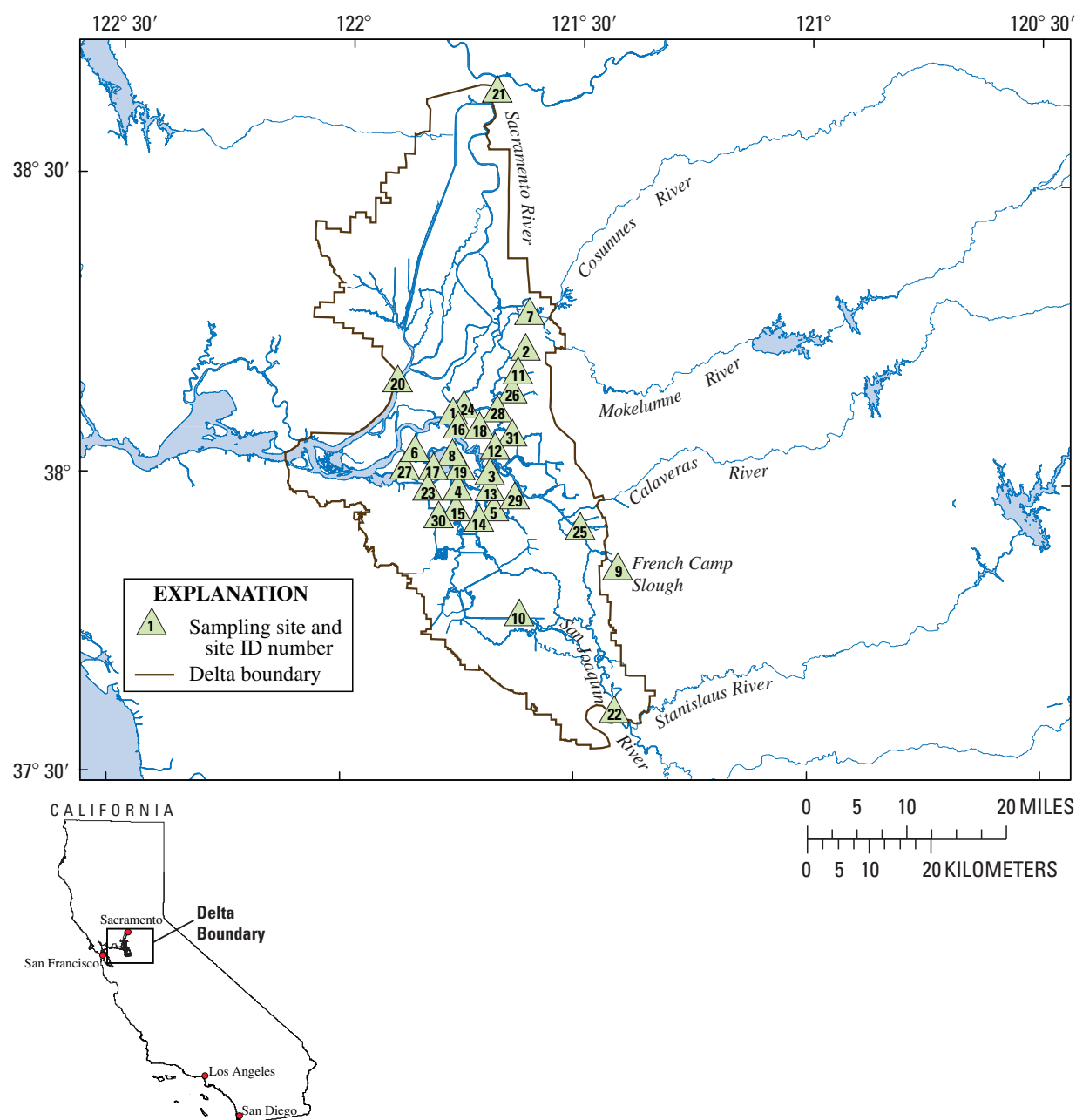


Figure 1. Location of water-quality sampling sites in the Sacramento–San Joaquin Delta, California. (See table 1 for site information.)

in summer 1994, and continuing through summer 1995, and again in summer 1996 (*table 1*). Water samples were typically collected once during each seasonal period, although not every site was sampled during each period. Samples were collected without regard to the tidal cycle.

Water samples were analyzed for 20 current-use pesticides by gas chromatography/mass spectrometry (GC/MS) at the U.S. Geological Survey's (USGS) organic chemistry laboratory in Sacramento, California. The USGS's National Research Program laboratory in Ft. Collins, Colorado, conducted the DOC analyses.

Purpose and Scope

The purpose of this report is to describe the methods and procedures used during sample collection and analysis, and presents analytical results for water samples collected during this study. Concentrations of 20 current-use pesticides analyzed in 153 water samples are presented. Dissolved organic carbon concentrations and water parameters analyzed in 132 water samples are also presented. Data contained in this report may be obtained in electronic format by contacting the USGS California Water Science Center's public information officer in Sacramento, California.

Acknowledgments

This report was prepared in cooperation with the California Bay-Delta Authority. The authors gratefully acknowledge James DeRose, Bryan Jennings and Rob Sheipline of the USGS for assistance with sample collection and logistical support during this project. The authors also wish to acknowledge Kathryn Crepeau and Dave Baston of the USGS for their many hours of laboratory work and pesticide analyses. The U.S. Geological Survey's Toxic Substances Hydrology Program and the California Bay-Delta Authority funded this project and the publication of this report.

Procedures and Methods

Description of Sampling Sites

Sampling sites were selected to provide a good spatial coverage of the Delta and its major tributaries. Thirty-one sites were sampled during the study. Four of these sites (*fig. 1*: sites 7, 9, 21, and 22) represent flows from major tributaries to the delta: site 7 for the Cosumnes and Mokelumne Rivers, site 9 for the French Camp Slough, site 21 for the Sacramento River system, and site 22 for the San Joaquin River system (*fig. 1, table 1*). Most of the remaining sites were located in the central portion of the Delta. In addition to acquiring a representative sampling of Delta waters from this hydrologically

complex area of interconnecting sloughs and channels, these sites were selected for their proximity to farmed Delta islands and their accessibility by boat.

Sample Collection

Water samples were collected either from bridges or by boat (*table 1*). All water samples were collected over a single vertical profile in the center of the channel using a USGS D77 depth-integrating sampler equipped with a 3-L Teflon bottle and nozzle. Sample water was poured directly from the 3-L Teflon collection bottle into 1-L and 250-mL baked, amber glass bottles for pesticide and DOC analysis respectively. Samples collected by boat were processed on site, whereas those collected from bridges were placed on ice and transported to the USGS's organic chemistry laboratory for processing. DOC samples were not collected during the summer 1996 sampling event.

Sample Processing and Analysis

Pesticide Samples

Water samples collected for pesticide analysis were filtered through baked, 0.7- μ m glass fiber filters within 24 hours of sampling, and a surrogate compound, terbutylazine, was added to provide quantitative data on extraction efficiency. Samples were then extracted onto C8 solid-phase extraction cartridges. The cartridges were dried using a syringe to force air repeatedly through each cartridge, frozen, and delivered to the USGS's organic chemistry laboratory, where they were stored frozen for up to 6 months. For analysis, the cartridges were thawed and then eluted with three 2-mL aliquots of hexane:diethyl ether (1:1). The eluate was concentrated and analyzed for 20 pesticides using a Varian gas chromatograph-mass spectrometer equipped with a Finnigan ion-trap detector. Details of the analytical method are described in Crepeau and others, 1994.

In addition to the 153 regular pesticide samples, another 53 samples were collected for quality control purposes, including 25 field equipment blanks and 28 replicate samples. Surrogate recovery in each sample was another type of quality control data evaluated during this study. None of the pesticides were detected in the field equipment blanks. For replicate samples, the relative percentage differences were less than 25 percent for all the pesticides detected. In all replicate pairs, each compound was either detected in both samples or not detected in both samples. Recovery of the surrogate, terbutylazine, was used to assess the efficiency of each extraction. The average percentage recovery and standard deviation for terbutylazine was calculated for each year. Sample data were excluded if the recovery of terbutylazine was outside the control limit of the annual mean plus or minus two standard deviations.

Table 1. List and location of sampling sites, sampling method, and seasonal sampling matrix for 1994–1996.

[All sites are located in California. DMS, °degree, minute, second"; id, identification]

Site name	USGS site id number	Site number	Latitude (DMS)	Longitude (DMS)	Sampling method	Summer 1994	Fall 1994	Winter 1994	Spring 1995	Summer 1995	Summer 1996
Mokelumne River at Andrus Island near Terminus	11336930	1	38°06'22"	121°34'16"	Boat	X		X	X	X	X
Beaver Slough near Thornton	381215121264901	2	38°12'15"	121°26'49"	Boat	X	X	X	X	X	X
Columbia Cut near Middle River	380125121303601	3	38°01'25"	121°30'36"	Boat		X	X	X	X	
Connection Slough near Middle River	380000121340801	4	38°00'00"	121°34'08"	Boat	X	X	X	X	X	
Empire Cut near Middle River	375817121300001	5	37°58'17"	121°30'00"	Boat		X	X	X	X	
False River near Oakley	11313440	6	38°03'21"	121°40'01"	Boat	X	X	X	X	X	X
Mokelumne River near Thornton	381519121262401	7	38°15'19"	121°26'24"	Bridge		X	X	X	X	
Old River at Franks Tract near Bethel Island	380300121344801	8	38°03'00"	121°34'48"	Boat		X	X	X	X	
French Camp Slough at French Camp	375320121160801	9	37°53'20"	121°16'08"	Bridge	X	X	X	X	X	X
Grant Line Canal at Tracy Road Bridge	11313200	10	37°49'15"	121°27'05"	Bridge	X		X	X	X	X
Hog Slough near Thornton	381009121273601	11	38°10'09"	121°27'36"	Boat		X	X	X		
Little Connection Slough near Terminus	380336121300201	12	38°03'36"	121°30'02"	Boat	X	X	X	X	X	
Middle River near Holt	11312685	13	38°00'11"	121°30'39"	Boat	X	X	X	X	X	
Middle River near Middle River	375721121314301	14	37°57'21"	121°31'43"	Bridge	X	X	X	X	X	X
Old River at Bacon Island	11313405	15	37°58'12"	121°34'20"	Boat	X	X	X	X	X	X
San Joaquin River at Bouldin Island near Terminus	380524121341201	16	38°05'24"	121°34'12"	Boat		X	X	X	X	
Piper Slough near Bethel Island	380148121365201	17	38°01'48"	121°36'52"	Boat		X	X	X	X	
Potato Slough near Terminus	380524121314801	18	38°05'24"	121°31'48"	Boat	X		X	X	X	
Old River at Quimby Island near Bethel Island	11311434	19	38°01'38"	121°33'52"	Boat		X	X	X	X	X
Sacramento River at Rio Vista	11455420	20	38°09'44"	121°41'28"	Bridge	X	X	X	X	X	
Sacramento River at Tower Bridge at Sacramento	383430121302001	21	38°34'30"	121°30'24"	Bridge		X	X	X	X	X
San Joaquin River at Vernalis	11303500	22	37°40'34"	121°15'59"	Bridge	X	X	X	X	X	X
Sand Mound Slough at Bethel Island	380000121373001	23	38°00'00"	121°37'30"	Boat	X	X	X	X	X	
South Mokelumne River near Iselton	380712121333601	24	38°07'12"	121°33'36"	Boat		X	X	X	X	
San Joaquin River near Stockton	375649121202100	25	37°56'49"	121°20'25"	Bridge	X	X	X	X	X	X
Sycamore Slough near Terminus	380831121281201	26	38°08'31"	121°28'12"	Boat	X		X	X	X	X
Taylor Slough near Bethel Island	380148121400401	27	38°01'48"	121°40'04"	Boat		X	X	X	X	
Little Potato Slough near Terminus	11336800	28	38°06'52"	121°29'50"	Boat			X	X	X	X
Turner Cut near Holt	11311300	29	37°59'33"	121°27'14"	Boat	X	X	X	X	X	X
Werner Slough near Knightsen	375737121361501	30	37°57'37"	121°36'15"	Boat	X	X	X	X	X	X
White Slough near Terminus	380448121280801	31	38°04'48"	121°28'08"	Boat		X	X	X	X	

DOC Samples and Water Parameters

Water samples collected for DOC analysis were filtered through a single 47-mm diameter, 0.45- μ m pore size, silver-metal filter, within 24 hours of sample collection. Samples were processed following the procedures described in the USGS Techniques of Water-Resources Investigations handbook (Wilde and others, 1999). The samples were filtered into 250-mL baked amber glass bottles, immediately placed on ice, and shipped within 24 hours to the USGS's National Research Program laboratory. Samples were analyzed for DOC concentration following the methods described in Aiken (1992).

Water parameters were measured on whole-water samples at the time of collection. Specific conductance and pH were measured using two handheld instruments (Cole Parmer, Model 141-61 and Orion Model 250A, respectively), following procedures outlined in the USGS's national field manual (Wilde and Radtke, 1998). Water temperature was measured using a digital thermometer.

Results of Dissolved Pesticide and DOC Analyses

This report presents dissolved pesticide and DOC concentrations and water-quality parameter values for surface-water samples collected during six seasons beginning in the summer of 1994. During the study, 153 water samples were analyzed for 20 current-use pesticides by GC/MS at the USGS's organic chemistry laboratory. DOC concentrations were analyzed in 132 field samples at the USGS's National Research Program laboratory. Results of these analyses are presented in the following tables: *table 2*, Water-quality parameters—1994 summer sampling; *table 3*, Pesticides—1994 summer sampling; *table 4*, Water-quality parameters—1994 fall sampling; *table 5*, Pesticides—1994 fall sampling; *table 6*, Water-quality parameters—1994 winter sampling; *table 7*, Pesticides—1994 winter sampling; *table 8*, Water-quality parameters—1995 spring sampling; *table 9*, Pesticides—1995 spring sampling; *table 10*, Water-quality parameters—1995 summer sampling; *table 11*, Pesticides—1995 summer sampling; *table 12*, Water-quality parameters—1996 summer sampling; and *table 13*, Pesticides—1996 summer sampling. Pesticides detected at concentrations below the method detection limits as reported in Crepeau and others (1994), are shown in parentheses because these values should be considered estimates. Significant figures were determined on the basis of the rounding method as described in American Society for Testing and Materials (1993).

Table 2. Water-quality parameters measured during the 1994 summer sampling season.

[Sites 3, 5, 7, 8, 11, 16, 17, 19, 21, 24, 27, 28, and 31 were not sampled during the period. Sites 2, 14, and 25 were each sampled twice during the sampling period. Numbers in brackets are USGS National Water Information System (NWIS) parameter codes. hh, hours; id, identification; mg/L, milligrams per liter; mm, minutes; mm/dd/yyyy, month/day/year; na, not analyzed; °C, degrees Celsius; μ S/cm, microsiemens per centimeter]

Site id number	Date (mm/dd/yyyy)	Time (hh:mm)	Temperature (°C) [00010]	pH [00400]	Specific conductance (μ S/cm) [00094]	Dissolved organic carbon (mg/L) [00681]
1	6/22/1994	18:49	22.6	7.72	172	1.8
2	6/7/1994	09:30	20.5	6.96	223	2.5
2	6/23/1994	15:42	na	7.62	109	2.0
4	6/21/1994	20:19	22.8	7.77	347	3.8
6	6/23/1994	10:58	22.1	7.85	612	2.3
9	6/7/1994	10:30	18.0	7.07	182	5.8
10	6/7/1994	14:00	21.5	7.74	556	3.8
12	6/22/1994	13:51	22.9	7.60	259	2.5
13	6/21/1994	19:53	22.8	7.71	330	2.4
14	6/7/1994	15:50	21.0	8.00	452	na
14	6/21/1994	12:54	na	7.19	407	3.8
15	6/22/1994	11:10	22.8	7.76	412	3.8
18	6/22/1994	13:17	22.8	7.77	192	2.3
20	6/8/1994	12:30	20.7	7.78	230	3.4
22	6/8/1994	13:00	25.5	7.96	963	na
23	6/23/1994	09:14	22.3	8.49	448	3.5
25	6/7/1994	16:50	22.4	7.68	820	8.8
25	6/21/1994	15:43	23.7	7.68	897	4.4
26	6/22/1994	16:47	19.0	7.62	176	2.5
29	6/21/1994	14:11	23.0	6.92	487	4.1
30	6/22/1994	09:04	22.7	7.65	447	4.5

Table 3. Pesticides detected during the 1994 summer sampling season.

[Sites 3, 5, 7, 8, 11, 16, 17, 19, 21, 24, 27, 28, and 31 were not sampled during the period. Sites 2, 14, and 25 were each sampled twice during the sampling period. The following pesticides were not detected in any samples: alachlor, butylate, chlorpyrifos, cyanazine, DCPA, fonofos, malathion, methidathion, napropamide, pebulate, and thiobencarb. Concentrations are shown in nanograms per liter. Numbers in brackets are USGS National Water Information System (NWIS) parameter codes. hh, hours; id, identification; mm, minutes; mm/dd/yyyy, month/day/year; nd, not detected; 5(), detected at a concentration less than the method detection limit]

Site id num- ber	Date (mm/dd/yyyy)	Time (hh:mm)	Atrazine [39632]	Carbaryl [49310]	Carbo- furan [49309]	Diazinon [62682]	EPTC [82668]	Meto- lachlor [39415]	Molinate [50375]	Simazine [04035]	Trifluralin [82661]
1	6/22/1994	18:49	nd	nd	nd	nd	nd	nd	nd	nd	nd
2	6/7/1994	09:30	nd	nd	nd	nd	nd	nd	977	nd	nd
2	6/23/1994	15:42	nd	nd	nd	nd	nd	nd	nd	nd	nd
4	6/21/1994	20:19	80	nd	nd	nd	nd	(14)	nd	69	nd
6	6/23/1994	10:58	43	nd	nd	nd	nd	nd	nd	67	nd
9	6/7/1994	10:30	nd	77	45	nd	878	1,160	1,090	127	(6)
10	6/7/1994	14:00	77	908	60	nd	nd	51	nd	72	nd
12	6/22/1994	13:51	78	nd	nd	nd	nd	(21)	nd	(60)	nd
13	6/21/1994	19:53	81	nd	nd	nd	nd	(11)	nd	65	nd
14	6/7/1994	15:50	nd	nd	nd	nd	(22)	(14)	nd	(55)	nd
14	6/21/1994	12:54	89	nd	nd	nd	nd	(15)	nd	70	nd
15	6/22/1994	11:10	61	nd	nd	nd	(69)	(12)	nd	63	nd
18	6/22/1994	13:17	67	nd	nd	nd	(50)	(25)	nd	nd	nd
20	6/8/1994	12:30	nd	nd	nd	nd	nd	nd	205	nd	nd
22	6/8/1994	13:00	nd	nd	nd	nd	(20)	(40)	nd	nd	(17)
23	6/23/1994	09:14	75	nd	nd	nd	nd	nd	nd	(62)	nd
25	6/7/1994	16:50	nd	nd	nd	nd	(73)	107	262	(56)	nd
25	6/21/1994	15:43	(23)	nd	nd	nd	134	124	nd	114	nd
26	6/22/1994	16:47	nd	nd	nd	nd	(59)	(29)	nd	nd	nd
29	6/21/1994	14:11	121	nd	nd	nd	(125)	(27)	nd	101	nd
30	6/22/1994	09:04	67	nd	nd	(15)	250	(33)	nd	73	nd

Table 4. Water-quality parameters measured during the 1994 fall sampling season.

[Sites 1, 10, 18, 26, and 28 were not sampled during the period. Numbers in brackets are USGS National Water Information System (NWIS) parameter codes. hh, hours; id, identification; mm, minutes; mg/L, milligrams per liter; mm/dd/yyyy, month/day/year; na, not analyzed; °C; degrees Celsius; µS/cm, microsiemens per centimeter]

Site id number	Date (mm/dd/yyyy)	Time (hh: mm)	Tempera- ture (°C) [00010]	pH [00400]	Specific conduc- tance (µS/cm) [00094]	Dissolved organic carbon (mg/L) [00681]
2	9/21/1994	14:40	22.3	7.65	220	3.4
3	9/26/1994	16:25	22.4	8.00	396	2.2
4	9/26/1994	15:32	22.0	7.38	445	2.5
5	9/26/1994	13:50	23.2	7.69	523	5.1
6	9/22/1994	14:12	20.7	8.13	991	1.8
7	9/21/1994	15:25	22.5	7.75	59	2.3
8	9/28/1994	10:45	19.5	7.60	675	2.2
9	9/23/1994	14:00	na	6.98	247	10.3
11	9/27/1994	09:15	20.8	7.28	191	3.5
12	9/27/1994	13:16	21.1	7.56	180	2.1
13	9/26/1994	15:52	22.5	7.77	411	3.2
14	9/26/1994	13:20	22.6	7.61	434	6.7
15	9/26/1994	12:19	21.7	7.11	867	2.9
16	9/28/1994	09:50	20.9	7.04	341	2.3
17	9/22/1994	14:35	21.1	7.89	1,127	3.1
19	9/28/1994	11:14	20.8	7.63	694	4.0
20	9/21/1994	13:20	20.5	7.69	225	2.0
21	9/21/1994	08:30	19.7	7.38	174	1.5
22	9/21/1994	10:00	22.7	7.34	845	3.1
23	9/22/1994	12:18	21.5	6.78	921	2.0
24	9/27/1994	16:00	21.0	7.63	176	2.1
25	9/23/1994	13:00	na	6.87	808	4.8
27	9/22/1994	13:23	21.7	8.08	1,013	4.8
29	9/26/1994	14:25	22.5	7.73	643	3.9
30	9/22/1994	16:25	21.5	8.05	882	3.4
31	9/27/1994	12:24	21.1	7.55	191	3.6

Table 5. Pesticides detected during the 1994 fall sampling season.

[Sites 1, 10, 18, 26, and 28 were not sampled during the period. The following pesticides were not detected in any samples: alachlor, atrazine, butylate, carbaryl, carbofuran, chlorpyrifos, cyanazine, diazinon, EPTC, fonofos, malathion, methidathion, molinate, napropamide, pebulate, simazine, thiobencarb, and trifluralin. Concentrations are shown in nanograms per liter. Numbers in brackets are USGS National Water Information System (NWIS) parameter codes. hh, hours; id, identification; mm, minutes; mm/dd/yyyy, month/day/year; nd, not detected; (), detected at a concentration less than the method detection limit]

Site id number	Date (mm/dd/yyyy)	Time (hh:mm)	DCPA [39771]	Meto-lachlor [39415]
2	9/21/1994	19:40	nd	nd
3	9/26/1994	16:25	nd	nd
4	9/26/1994	15:32	nd	nd
5	9/26/1994	13:50	nd	(22)
6	9/22/1994	14:12	nd	nd
7	9/28/1994	10:45	nd	nd
8	9/21/1994	15:25	nd	nd
9	9/23/1994	14:00	nd	71
11	9/27/1994	19:15	nd	nd
12	9/27/1994	13:16	nd	nd
13	9/26/1994	15:52	nd	nd
14	9/26/1994	13:20	nd	nd
15	9/26/1994	12:19	nd	nd
16	9/28/1994	09:50	nd	nd
17	9/22/1994	14:35	nd	nd
19	9/28/1994	11:14	nd	nd
20	9/21/1994	13:20	nd	nd
21	9/21/1994	08:30	nd	nd
22	9/21/1994	10:00	nd	nd
23	9/22/1994	12:18	nd	nd
24	9/27/1994	16:00	nd	nd
25	9/23/1994	13:00	nd	(33)
27	9/22/1994	13:23	nd	nd
29	9/26/1994	14:25	(20)	(39)
30	9/22/1994	16:25	nd	nd
31	9/27/1994	12:24	nd	nd

Table 6. Water-quality parameters measured during the 1994 winter sampling season.

[Site 31 was not sampled during the period. Numbers in brackets are USGS National Water Information System (NWIS) parameter codes. hh, hours; id, identification; mg/L, milligrams per liter; mm, minutes; mm/dd/yyyy, month/day/year; na, not analyzed; °C, degrees Celsius; µS/cm, microsiemens per centimeter]

Site id number	Date (mm/dd/yyyy)	Time (hh:mm)	Tem- perature (°C) [00010]	pH [00400]	Specific conduc- tance (µS/cm) [00094]	Dis- solved organic carbon (mg/L) [00681]
1	11/30/1994	12:31	10.5	7.70	224	3.0
2	12/5/1994	10:15	9.3	7.21	237	4.1
3	11/29/1994	12:30	10.3	7.50	387	na
4	11/29/1994	11:26	9.7	7.63	554	3.7
5	11/29/1994	13:26	10.5	7.45	542	4.2
6	12/1/1994	13:07	10.6	8.00	2,840	3.0
7	12/5/1994	09:50	9.7	7.25	147	6.5
8	11/30/1994	13:36	10.5	7.71	583	3.5
9	12/5/1994	16:00	9.7	7.20	855	4.8
10	12/5/1994	14:22	10.1	6.67	1,020	4.1
11	11/30/1994	09:47	9.9	7.81	181	3.0
12	11/29/1994	15:30	9.9	7.74	259	4.3
13	11/29/1994	11:55	9.8	7.58	384	3.7
14	12/5/1994	13:40	10.2	7.58	550	3.8
15	11/29/1994	10:15	9.4	7.76	721	3.8
16	11/30/1994	13:10	10.6	7.76	413	2.9
17	12/1/1994	14:13	10.4	7.88	1,700	2.5
18	11/29/1994	16:05	9.8	7.97	244	4.3
19	11/30/1994	13:56	10.5	7.82	580	3.5
20	12/5/1994	11:40	8.8	7.53	245	6.7
21	12/5/1994	08:40	10.0	6.54	160	na
22	12/5/1994	15:20	10.5	7.36	929	5.3
23	12/1/1994	11:27	9.1	7.83	1,065	3.5
24	11/30/1994	11:36	10.8	7.65	207	2.8
25	12/5/1994	13:00	9.7	7.32	954	4.6
26	11/30/1994	08:53	9.8	7.37	245	3.2
27	12/1/1994	12:20	9.7	7.87	1,201	3.2
28	11/30/1994	10:55	10.5	7.64	207	4.0
29	11/29/1994	14:05	10.1	7.51	636	4.5
30	11/29/1994	19:07	8.9	6.99	737	5.2

Table 7. Pesticides detected during the 1994 winter sampling season.

[Site 31 was not sampled during the period. The following pesticides were not detected in any samples: alachlor, atrazine, butylate, carbaryl, carbofuran, chlorpyrifos, cyanazine, DCPA, diazinon, EPTC, fonofos, malathion, methidathion, metolachlor, molinate, napropamide, pebulate, thiobencarb, and trifluralin. Concentrations are shown in nanograms per liter. Numbers in brackets are USGS National Water Information System (NWIS) parameter codes. hh, hours; id, identification; mm, minutes; mm/dd/yyyy, month/day/year; nd, not detected]

Site id number	Date (mm/dd/yyyy)	Time (hh:mm)	Simazine [04035]
1	11/30/1994	12:31	496
2	12/5/1994	10:15	90
3	11/29/1994	12:30	242
4	11/29/1994	11:26	235
5	11/29/1994	13:26	223
6	12/1/1994	13:07	223
7	12/5/1994	09:50	357
8	11/30/1994	13:36	186
9	12/5/1994	16:00	nd
10	12/5/1994	14:22	120
11	11/30/1994	09:47	227
12	11/29/1994	15:30	132
13	11/29/1994	11:55	212
14	12/5/1994	13:40	165
15	11/29/1994	10:15	191
16	11/30/1994	13:10	184
17	12/1/1994	14:13	172
18	11/29/1994	16:05	223
19	11/30/1994	13:56	207
20	12/5/1994	11:40	118
21	12/5/1994	08:40	912
22	12/5/1994	15:20	171
23	12/1/1994	11:27	207
24	11/30/1994	11:36	448
25	12/5/1994	13:00	457
26	11/30/1994	08:53	180
27	12/1/1994	12:20	169
28	11/30/1994	10:55	299
29	11/29/1994	14:05	138
30	11/29/1994	09:07	(42)

Table 8. Water-quality parameters measured during the 1995 spring sampling season.

[Numbers in brackets are USGS National Water Information System (NWIS) parameter codes. hh, hours; id, identification; mg/L, milligrams per liter; mm, minutes; mm/dd/yyyy, month/day/year; na, not analyzed; °C, degrees Celsius; µS/cm, microsiemens per centimeter]

Site id number	Date (mm/dd/yyyy)	Time (hh:mm)	Tempera- ture (°C) [00010]	pH [00400]	Specific conduc- tance (µS/cm) [00094]	Dissolved organic carbon (mg/L) [00681]
1	3/29/1995	11:55	10.8	7.40	127	3.1
2	4/4/1995	13:05	18.0	7.35	627	10.4
3	3/28/1995	15:00	12.3	7.42	288	5.6
4	3/28/1995	12:42	12.1	7.38	368	5.5
5	3/28/1995	13:15	12.3	7.37	378	5.7
6	3/29/1995	09:22	11.7	7.13	336	4.8
7	4/4/1995	12:30	15.3	7.65	90	1.9
8	3/29/1995	12:52	12.5	7.35	392	5.5
9	4/4/1995	15:40	20.5	7.67	264	6.3
10	4/5/1995	11:35	16.5	7.11	247	na
11	3/29/1995	08:00	11.7	6.85	632	5.7
12	3/28/1995	16:30	11.3	7.15	256	4.4
13	3/29/1995	15:27	12.4	7.27	393	na
14	4/5/1995	12:15	17.7	7.73	277	4.4
15	3/28/1995	10:51	11.7	7.42	370	4.7
16	3/29/1995	12:26	12.0	7.29	292	5.2
17	3/29/1995	09:58	12.4	7.21	371	5.1
18	3/28/1995	16:56	11.3	7.35	168	4.1
19	3/29/1995	14:30	12.3	7.28	401	5.6
20	4/5/1995	16:00	15.2	7.58	259	2.3
21	4/4/1995	10:55	12.4	7.24	135	1.4
22	4/4/1995	14:48	15.8	8.14	300	3.3
23	3/29/1995	16:57	12.8	7.40	418	5.5
24	3/29/1995	11:11	11.3	7.34	143	4.0
25	4/4/1995	16:15	16.7	7.75	255	3.7
26	3/29/1995	08:49	11.9	7.66	256	6.1
27	3/29/1995	08:33	12.4	7.12	614	8.1
28	3/29/1995	10:30	11.6	7.33	170	4.2
29	3/28/1995	13:55	12.5	7.37	323	5.6
30	3/28/1995	09:50	11.5	7.34	481	5.6
31	3/28/1995	17:53	11.5	7.34	174	3.9

Table 9. Pesticides detected during the 1995 spring sampling season.

[The following pesticides were not detected in any samples: alachlor, atrazine, butylate, carbaryl, cyanazine, DCPA, EPTC, fonofos, malathion, methidathion, molinate, napropamide, pebulate, thiobencarb, and trifluralin. Concentrations are shown in nanograms per liter. Numbers in brackets are USGS National Water Information System (NWIS) parameter codes. hh, hours; id, identification; mm, minutes; mm/dd/yyyy, month/day/year; nd, not detected; (), detected at a concentration less than the method detection limit]

Site id number	Date (mm/dd/yyyy)	Time (hh:mm)	Carbofuran [49309]	Chlorpyrifos [38933]	Diazinon [62682]	Metolachlor [39415]	Simazine [04035]
1	3/29/1995	11:55	nd	nd	nd	nd	66
2	4/4/1995	13:05	958	36	(29)	53	761
3	3/28/1995	15:00	nd	nd	nd	nd	145
4	3/28/1995	12:42	37	nd	nd	nd	134
5	3/28/1995	13:15	nd	nd	nd	nd	137
6	3/29/1995	09:22	79	nd	nd	(16)	137
7	4/4/1995	12:30	nd	nd	nd	nd	nd
8	3/29/1995	12:52	144	nd	nd	(14)	142
9	4/4/1995	15:40	nd	nd	nd	nd	73
10	4/5/1995	11:35	nd	nd	nd	nd	nd
11	3/29/1995	08:00	nd	nd	nd	(14)	73
12	3/28/1995	16:30	nd	nd	nd	(11)	84
13	3/29/1995	15:27	130	nd	nd	nd	137
14	4/5/1995	12:15	nd	nd	nd	nd	nd
15	3/28/1995	10:51	nd	nd	nd	nd	127
16	3/29/1995	12:26	64	nd	nd	(16)	125
17	3/29/1995	09:58	130	nd	nd	nd	138
18	3/28/1995	16:56	nd	nd	nd	nd	84
19	3/29/1995	14:30	92	nd	nd	nd	122
20	4/5/1995	16:00	nd	nd	nd	nd	nd
21	4/4/1995	10:55	nd	nd	nd	nd	nd
22	4/4/1995	14:48	nd	nd	nd	nd	nd
23	3/29/1995	16:57	138	nd	nd	(18)	143
24	3/29/1995	11:11	nd	nd	nd	nd	129
25	4/4/1995	16:15	nd	nd	nd	nd	67
26	3/29/1995	08:49	nd	nd	nd	nd	200
27	3/29/1995	08:33	66	nd	nd	nd	141
28	3/29/1995	10:30	nd	nd	nd	nd	73
29	3/28/1995	13:55	nd	nd	nd	nd	140
30	3/28/1995	09:50	114	nd	nd	60	139
31	3/28/1995	17:53	nd	nd	nd	nd	79

Table 10. Water-quality parameters measured during the 1995 summer sampling season.

[Site 11 was not sampled during the period. Numbers in brackets are USGS National Water Information System (NWIS) parameter codes. hh, hours; id, identification; mg/L, milligrams per liter; mm, minutes; mm/dd/yyyy, month/day/year; °C; degrees Celsius; $\mu\text{S}/\text{cm}$, microsiemens per centimeter]

Site id number	Date (mm/dd/yyyy)	Time (hh:mm)	Temperature (°C) [00010]	pH [00400]	Specific conductance ($\mu\text{S}/\text{cm}$) [00094]	Dissolved or- ganic carbon (mg/L) [00681]
1	6/2/1995	08:41	17.0	7.37	92	2.5
2	6/7/1995	15:38	18.0	7.28	205	5.0
3	6/1/1995	15:34	20.0	7.16	134	3.2
4	5/30/1995	12:51	19.4	7.06	161	3.8
5	6/1/1995	13:36	21.0	6.92	162	4.0
6	5/26/1995	11:40	18.1	7.59	158	3.7
7	6/7/1995	14:30	17.0	6.75	69	3.0
8	5/26/1995	09:18	18.0	7.09	160	5.1
9	6/8/1995	11:50	17.0	7.44	215	10.4
10	6/8/1995	12:30	15.2	7.54	146	2.7
12	6/1/1995	16:17	20.0	7.16	137	4.8
13	5/30/1995	13:19	19.7	6.93	164	4.0
14	6/1/1995	12:05	20.0	6.81	149	6.1
15	5/30/1995	08:29	18.7	6.69	165	4.6
16	6/2/1995	09:53	19.0	7.24	116	3.8
17	5/26/1995	12:12	18.5	7.37	158	3.4
18	6/2/1995	09:32	19.0	7.24	93	2.6
19	5/26/1995	08:56	18.0	6.72	162	5.1
20	6/8/1995	09:30	11.5	7.34	116	2.7
21	6/5/1995	09:55	15.0	6.78	90	2.1
22	6/5/1995	11:30	14.5	6.86	136	4.2
23	5/26/1995	09:58	18.4	7.30	162	5.9
24	6/2/1995	08:10	17.0	7.10	88	1.4
25	6/8/1995	10:45	7.0	7.33	133	3.4
26	6/2/1995	21:22	21.0	8.10	71	2.4
27	5/26/1995	10:55	18.6	7.55	254	4.6
28	6/1/1995	20:00	19.0	7.28	92	4.3
29	6/1/1995	14:14	21.0	7.05	148	4.2
30	5/30/1995	11:16	19.6	7.06	191	4.1
31	6/1/1995	19:07	21.0	7.46	88	2.7

Table 11. Pesticides detected during the 1995 summer sampling season.

[Site 11 was not sampled during the period. The following pesticides were not detected in any samples: alachlor, atrazine, butylate, carbaryl, carbofuran, chlorpyrifos, cyanazine, DCPA, fonofos, malathion, methidathion, napropamide, pebulate, thiobencarb, and trifluralin. Concentrations are shown in nanograms per liter. Numbers in brackets are USGS National Water Information System (NWIS) parameter codes. hh, hours; id, identification; mm, minutes; mm/dd/yyyy, month/day/year; nd, not detected; (), detected at a concentration less than the method detection limit]

Site id number	Date (mm/dd/yyyy)	Time (hh:mm)	Diazinon [62682]	EPTC [82668]	Meto- lachlor [39415]	Molinate [50375]	Simazine [04035]
1	6/2/1995	08:41	nd	nd	nd	148	nd
2	6/7/1995	15:38	nd	nd	nd	nd	nd
3	6/1/1995	15:34	nd	nd	(17)	nd	nd
4	5/30/1995	12:51	nd	nd	(22)	nd	nd
5	6/1/1995	13:36	nd	(15)	(16)	nd	nd
6	5/26/1995	11:40	nd	(43)	(19)	nd	nd
7	6/7/1995	14:30	nd	nd	nd	nd	nd
8	5/26/1995	09:18	nd	(48)	(15)	nd	nd
9	6/8/1995	11:50	nd	139	148	441	116
10	6/8/1995	12:30	nd	nd	(16)	nd	nd
12	6/1/1995	16:17	nd	(20)	(14)	nd	nd
13	5/30/1995	13:19	nd	nd	(19)	nd	nd
14	6/1/1995	12:05	nd	(17)	(15)	nd	nd
15	5/30/1995	08:29	nd	160	(17)	nd	nd
16	6/2/1995	09:53	nd	nd	nd	nd	nd
17	5/26/1995	12:12	nd	(62)	(22)	nd	nd
18	6/2/1995	09:32	nd	nd	nd	nd	nd
19	5/26/1995	08:56	nd	(29)	(19)	nd	nd
20	6/8/1995	09:30	nd	nd	nd	119	nd
21	6/5/1995	09:55	nd	nd	nd	242	nd
22	6/5/1995	11:30	nd	nd	(11)	nd	nd
23	5/26/1995	09:58	nd	(79)	(16)	nd	nd
24	6/2/1995	08:10	nd	nd	nd	108	nd
25	6/8/1995	10:45	nd	nd	(31)	nd	nd
26	6/2/1995	21:22	nd	nd	nd	nd	nd
27	5/26/1995	10:55	nd	nd	(19)	nd	nd
28	6/1/1995	20:00	nd	nd	nd	73	nd
29	6/1/1995	14:14	nd	nd	(14)	nd	nd
30	5/30/1995	11:16	(19)	176	(33)	nd	nd
31	6/1/1995	19:07	nd	nd	nd	nd	nd

Table 12. Water-quality parameters measured during the 1996 summer sampling season.

[Sites 3, 4, 5, 7, 8, 11, 12, 13, 16, 17, 18, 20, 23, 24, 27, and 31 were not sampled during the period. Numbers in brackets are USGS National Water Information System (NWIS) parameter codes. hh, hours; id, identification; mm, minutes; mm/dd/yyyy, month/day/year; na, not analyzed; °C; degrees Celsius; µS/cm, microsiemens per centimeter]

Site id number	Date (mm/dd/yyyy)	Time (hh:mm)	Temperature (°C) [00010]	pH [00400]	Specific conductance (µS/cm) [00094]
1	6/28/1996	11:06	19.7	7.41	118
2	6/28/1996	18:47	19.7	7.46	61
6	6/26/1996	18:57	21.0	7.83	114
9	7/1/1996	12:15	24.2	7.68	133
10	7/1/1996	14:00	25.1	na	na
14	6/26/1996	13:32	22.1	7.72	173
15	6/26/1996	14:26	21.6	7.46	120
19	6/26/1996	12:14	21.3	6.94	160
21	7/1/1996	10:35	21.1	7.75	111
22	7/1/1996	13:10	25.0	7.59	586
25	6/27/1996	13:47	20.8	7.37	614
26	6/28/1996	09:04	19.5	7.19	93
28	6/27/1996	17:24	21.1	7.49	140
29	6/27/1996	11:40	22.1	7.00	396
30	6/26/1996	15:23	22.5	7.69	132

Table 13. Pesticides detected during the 1996 summer sampling season.

[Sites 3, 4, 5, 7, 8, 11, 12, 13, 16, 17, 18, 20, 23, 24, 27, and 31 were not sampled during the period. The following pesticides were not detected in any samples: alachlor, atrazine, butylate, carbofuran, cyanazine, DCPA, diazinon, fonofos, malathion, methidathion, napropamide, pebulate, and thiobencarb. Concentrations are shown in nanograms per liter. Numbers in brackets are USGS National Water Information System (NWIS) parameter codes. hh, hours; id, identification; mm, minutes; mm/dd/yyyy, month/day/year; nd, not detected, (), detected at a concentration less than the method detection limit]

Site id number	Date (mm/dd/yyyy)	Time (hh:mm)	Carbaryl [49310]	Chlorpyrifos [38933]	EPTC [82668]	Metolachlor [39415]	Molinate [50375]	Simazine [04035]	Trifluralin [82661]
1	6/28/1996	11:06	nd	nd	nd	nd	244	nd	nd
2	6/28/1996	18:47	nd	nd	nd	72	nd	nd	nd
6	6/26/1996	18:57	nd	nd	nd	nd	242	nd	nd
9	7/1/1996	12:15	76.5	(28)	(28)	141	(25)	(23)	nd
10	7/1/1996	14:00	nd	nd	(87)	100	nd	nd	nd
14	6/26/1996	13:32	nd	nd	(35)	(23)	193	nd	nd
15	6/26/1996	14:26	nd	nd	(18)	(11)	208	nd	nd
19	6/26/1996	12:14	nd	nd	(22)	(12)	218	nd	nd
21	7/1/1996	10:35	nd	nd	nd	nd	116	nd	nd
22	7/1/1996	13:10	nd	nd	(50)	(44)	(17)	nd	(11)
25	6/27/1996	13:47	nd	nd	(62)	188	(14)	(11)	nd
26	6/28/1996	09:04	nd	nd	nd	71	111	nd	nd
28	6/27/1996	17:24	nd	nd	nd	nd	269	nd	nd
29	6/27/1996	11:40	nd	nd	(42)	67	65	nd	nd
30	6/26/1996	15:23	111	nd	(18)	(13)	163	nd	nd

During this study, 11 current-use pesticides were detected, and maximum concentrations ranged from 17 ng/L for trifluralin to 1,160 ng/L for metolachlor. The highest concentrations of five pesticides (carbaryl, carbofuran, metolachlor, molinate, and simazine) were greater than 900 ng/L. Metolachlor and simazine were the most frequently detected pesticides (37 and 46 percent of all samples, respectively) and were observed in five out of the six sampling seasons (*table 14*). EPTC and molinate were detected in 20 and 15 percent of all samples, respectively, and were detected only during the three summer sampling seasons (*table 14*).

Seasonally, the greatest number of pesticides and the largest concentrations for 6 of the 11 pesticides were detected in the summer sampling events. In contrast, only DCPA and metolachlor were detected in the fall 1994 sampling event and only simazine was detected in the winter 1994 sampling event. It should be noted that sampling during this study was not timed to follow rainfall events, and many studies have documented elevated concentrations of multiple pesticides in surface waters following storm events (Kuivila and Foe, 1995; Orlando and others, 2003 and 2004). Greater numbers of pesticides were detected during the spring 1995, summer 1995, and summer 1996 sampling events than in the previous fall and winter

samplings. Maximum concentrations were generally much higher for those pesticides that were detected in the summer of 1994 as compared with detections in the summers of 1995 and 1996 (*table 14*).

A comparison of pesticide detections may be made between the spring and summer 1995 seasons. During these two seasons, 30 identical sites were sampled, which provides a good basis for comparison. Five pesticides were detected in each season; three, diazinon, metolachlor, and simazine, were detected in both seasons (*tables 9 and 11*). The insecticides carbofuran and chlorpyrifos, which are applied to alfalfa, were detected in spring 1995, whereas EPTC and molinate, herbicides used on alfalfa and rice, respectively, were detected in summer 1995 (*fig. 2*). Diazinon was detected in only one sample in each season, but not at the same site, and at concentrations less than 30 ng/L. Metolachlor was detected at numerous sites, mainly in the central Delta, in both seasons, and concentrations were generally less than 35 ng/L (*fig. 3*). Simazine was observed at sites throughout the central Delta in spring 1995 at concentrations greater than 100 ng/L, but was present in only one sample during the summer sampling event.

Table 14. Seasonal detections of pesticides 1994–1996.

[Values are percent detected out of the total number of samples analyzed in a given season; number in parentheses is the maximum concentration detected for a particular compound, in nanograms per liter. Numbers in brackets are USGS National Water Information System (NWIS) parameter codes]

	Total num- ber of samples analyzed	Atrazine [39632]	Car- baryl [49310]	Carbo- furan [49309]	Chlor- pyrifos [38933]	DCPA [39771]	Diazi- non [62682]	EPTC [82668]	Meto- lachlor [39415]	Mo- linat [50375]	Sima- zine [04035]	Triflu- ralin [82661]
Summer 1994	21	57.1 (121)	9.5 (908)	9.5 (60)			4.8 (15)	47.6 (878)	71.4 (1,160)	19.0 (1,090)	66.7 (127)	9.5 (17)
Fall 1994	26					3.8 (20)			15.4 (71)			
Winter 1994	30										96.7 (912)	
Spring 1995	31			35.5 (958)	3.2 (36)		3.2 (29)		25.8 (60)		80.6 (761)	
Summer 1995	30						3.3 (19)	36.7 (176)	63.3 (148)	20.0 (441)	3.3 (116)	
Summer 1996	15		13.3 (111)		6.7 (28)			60.0 (87)	73.3 (188)	86.7 (269)	13.3 (23)	6.7 (11)

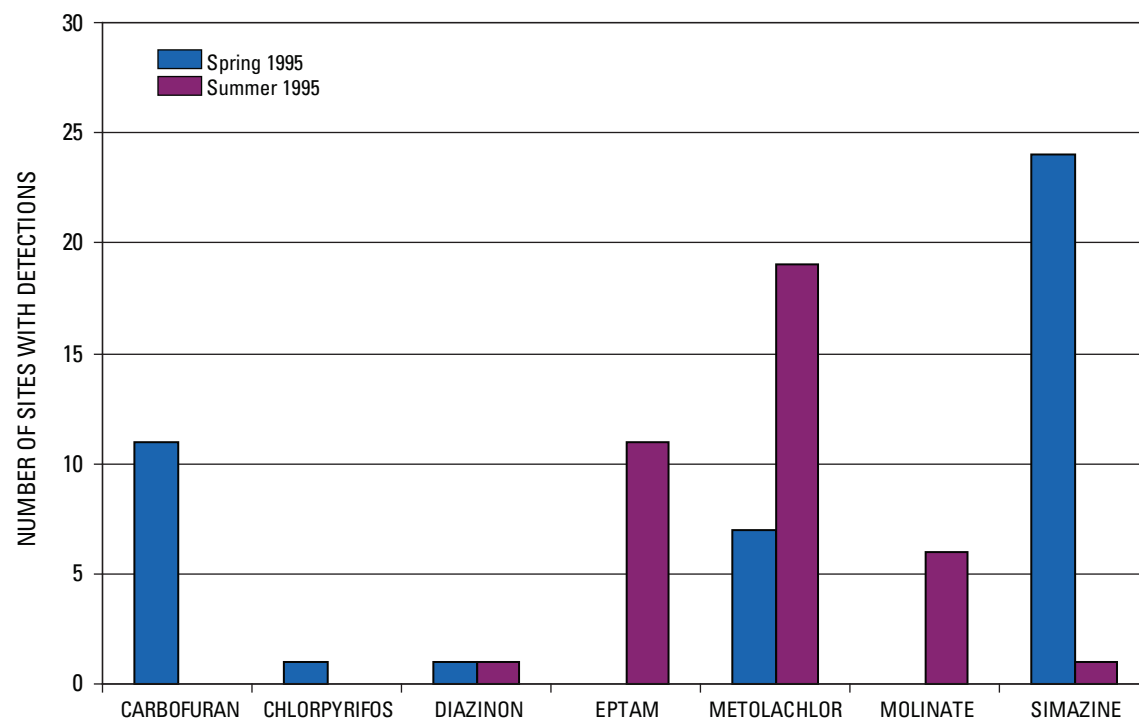


Figure 2. Number of sites with pesticide detections in spring and summer 1995.

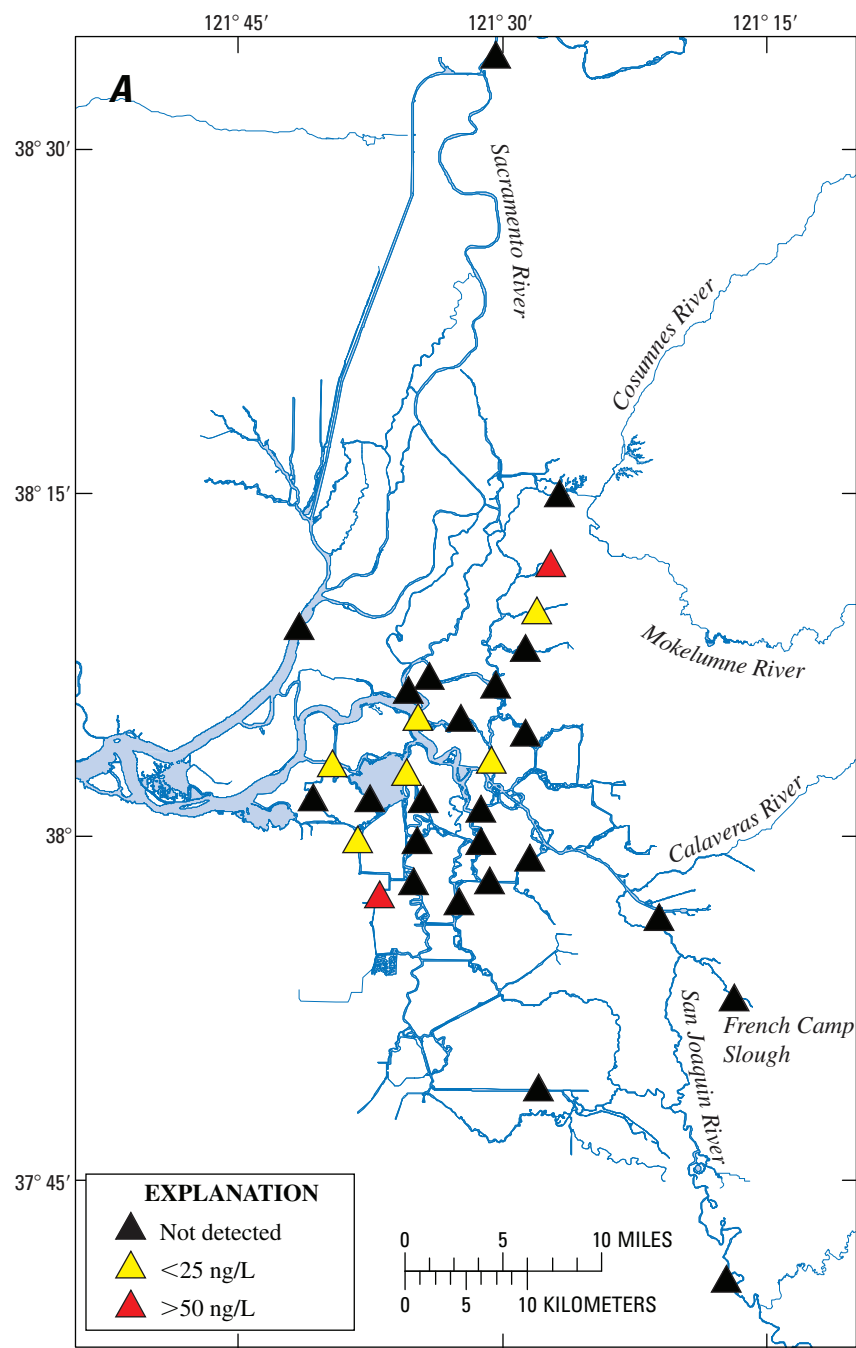


Figure 3. Metolachlor detections during the spring (A) and summer (B) of 1995.

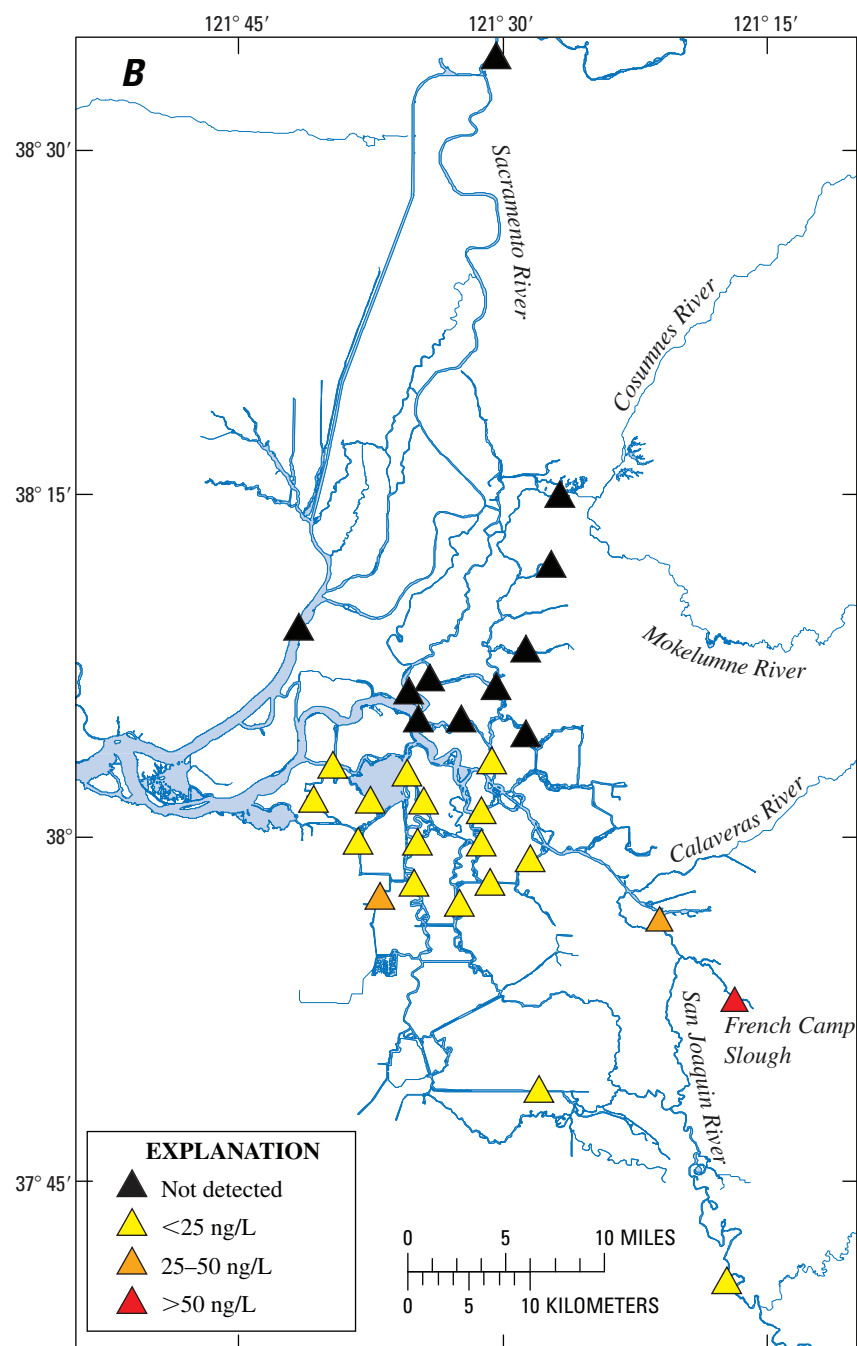


Figure 3B. Continued.

Comparison of the three summer sampling seasons shows that more individual pesticides were detected, and with generally higher maximum concentrations, in the summer of 1994 than in 1995 or 1996. Nine pesticides were found in samples from summer 1994, whereas five were detected in 1995 and seven in 1996. EPTC, metolachlor, molinate, and simazine were detected during each summer sampling event, though only metolachlor was detected in greater than 50 percent of the samples collected in each summer. Detection frequencies of molinate

and simazine were each above 20 percent in only one of the three summers, 1996 and 1994 respectively. Detection frequencies for all pesticides were generally lowest in summer 1995 (table 14). Both metolachlor and EPTC were primarily found at sites in the central and southern Delta (figs. 4 and 5). In 1994 and 1995, molinate was detected in the north Delta and French Camp Slough, whereas in 1996 it was present throughout the central Delta (fig. 6).

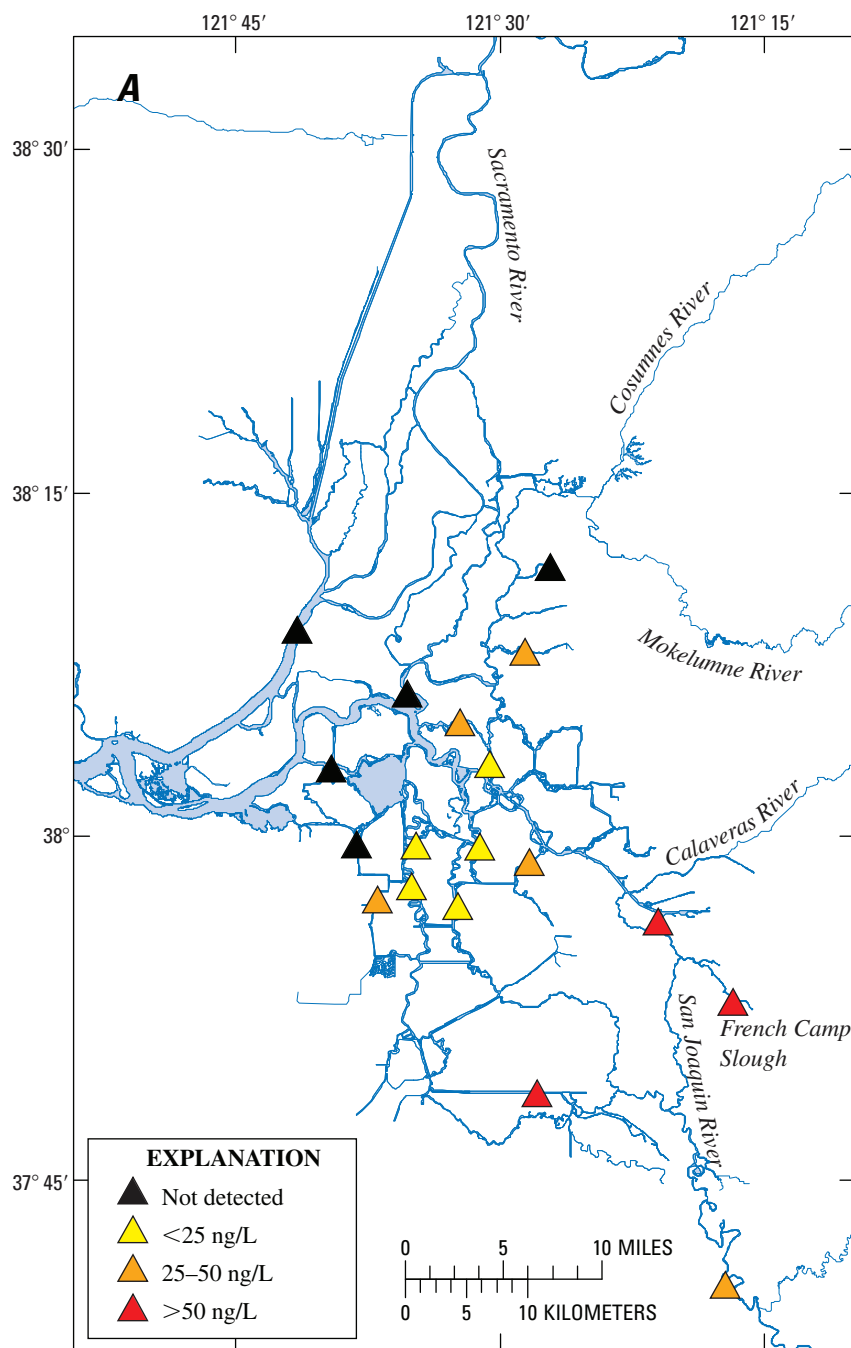


Figure 4. Metolachlor detections in the summer of 1994 (A), 1995 (B), and 1996 (C).

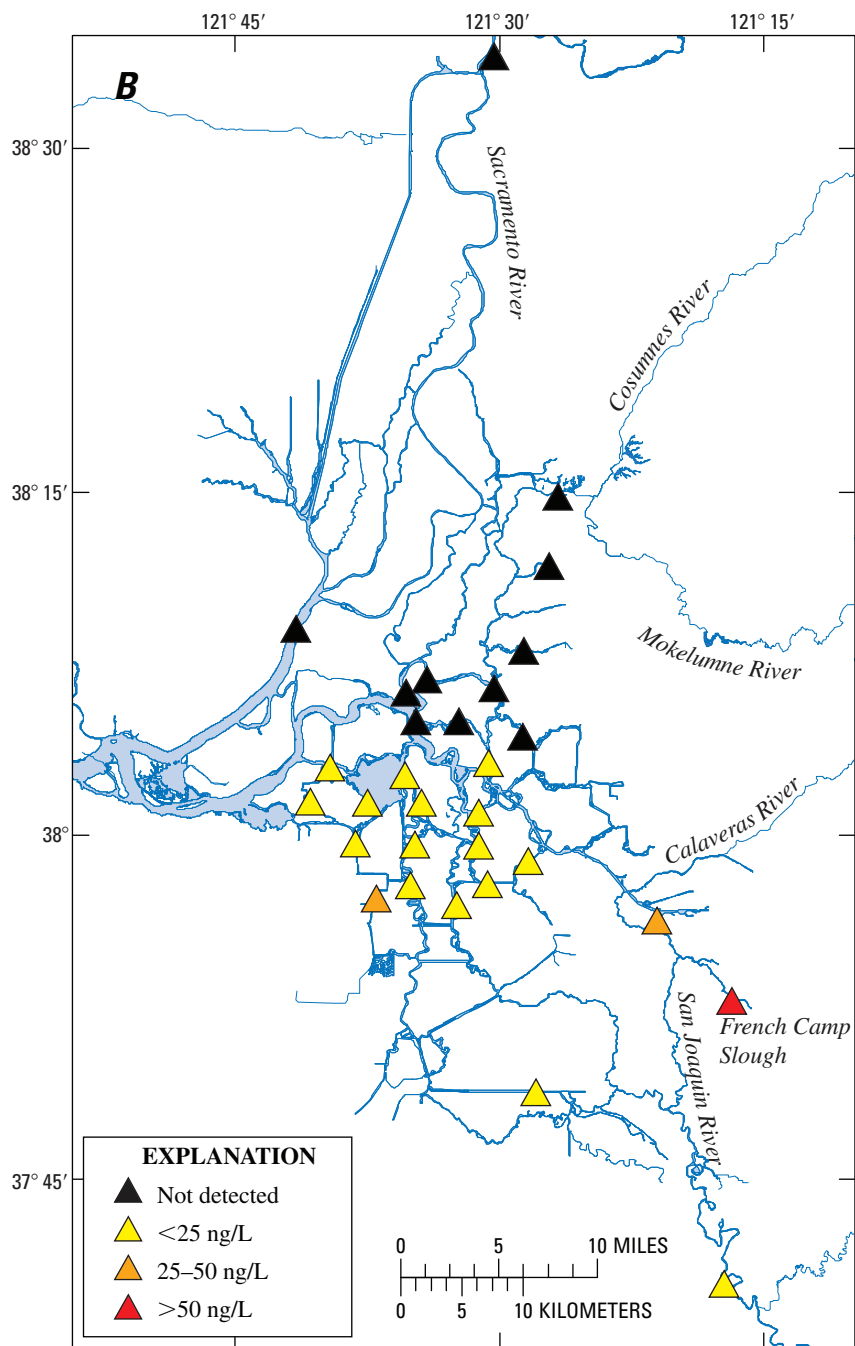


Figure 4B. Continued.

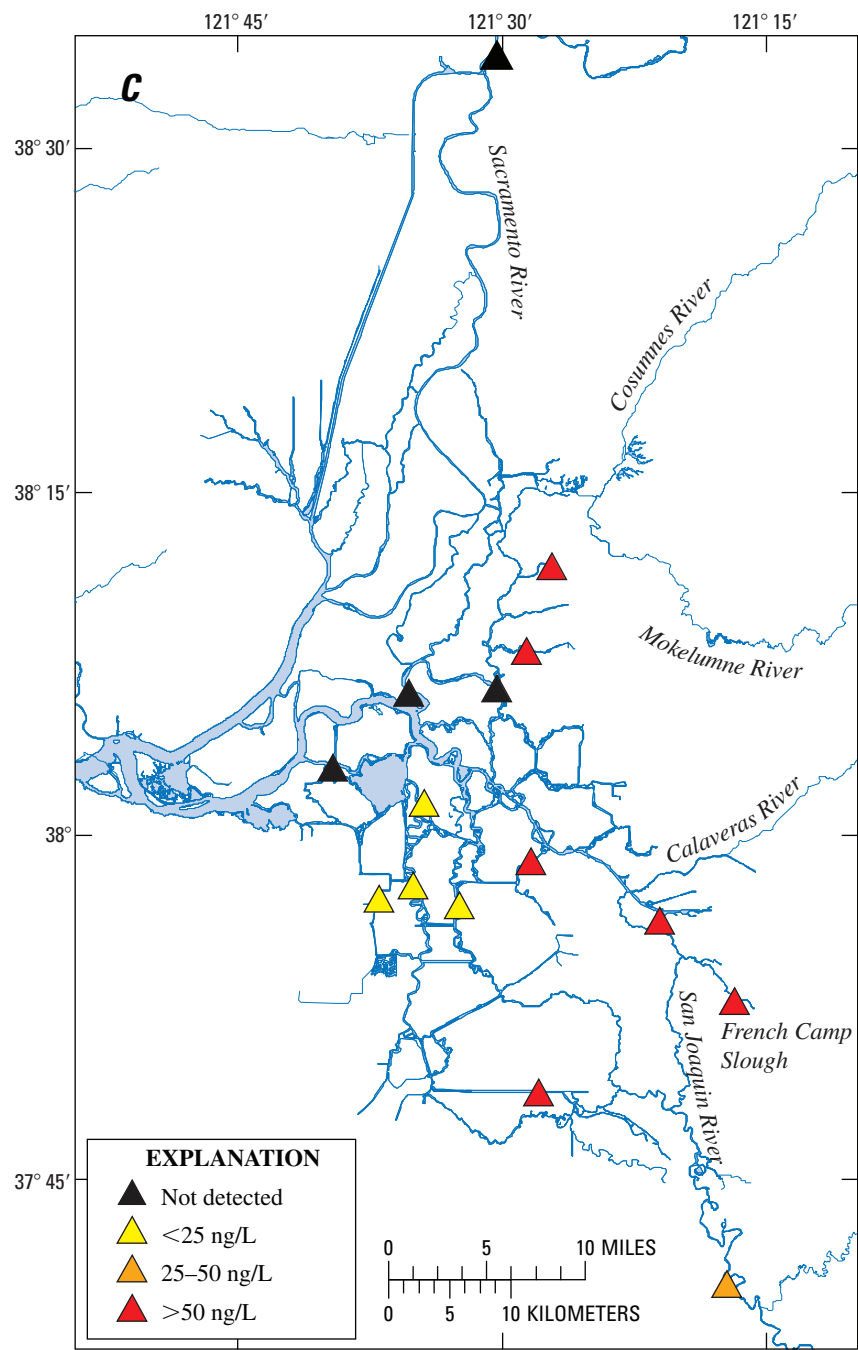


Figure 4C. Continued.

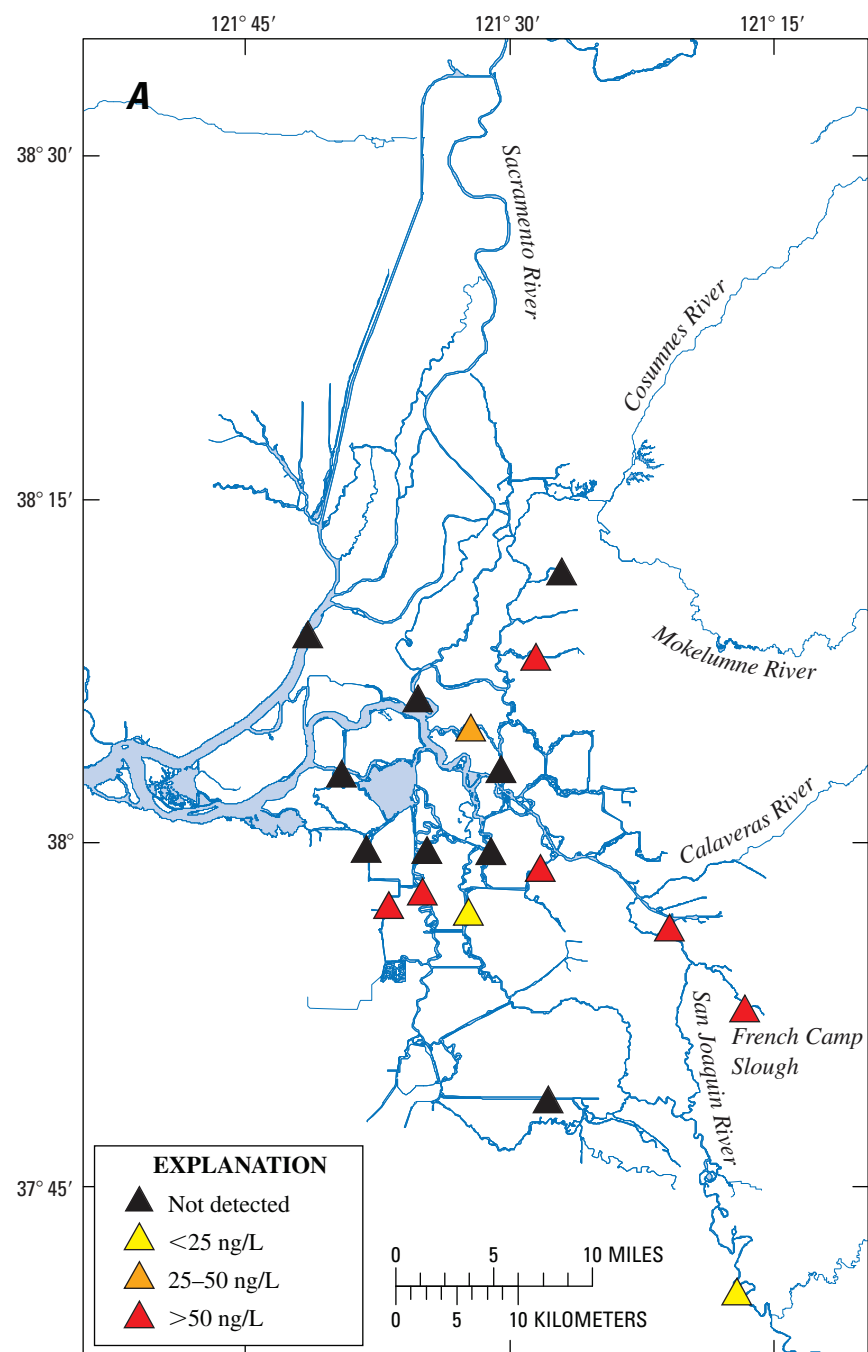


Figure 5. EPTC detections in the summer of 1994 (A), 1995 (B), and 1996 (C).

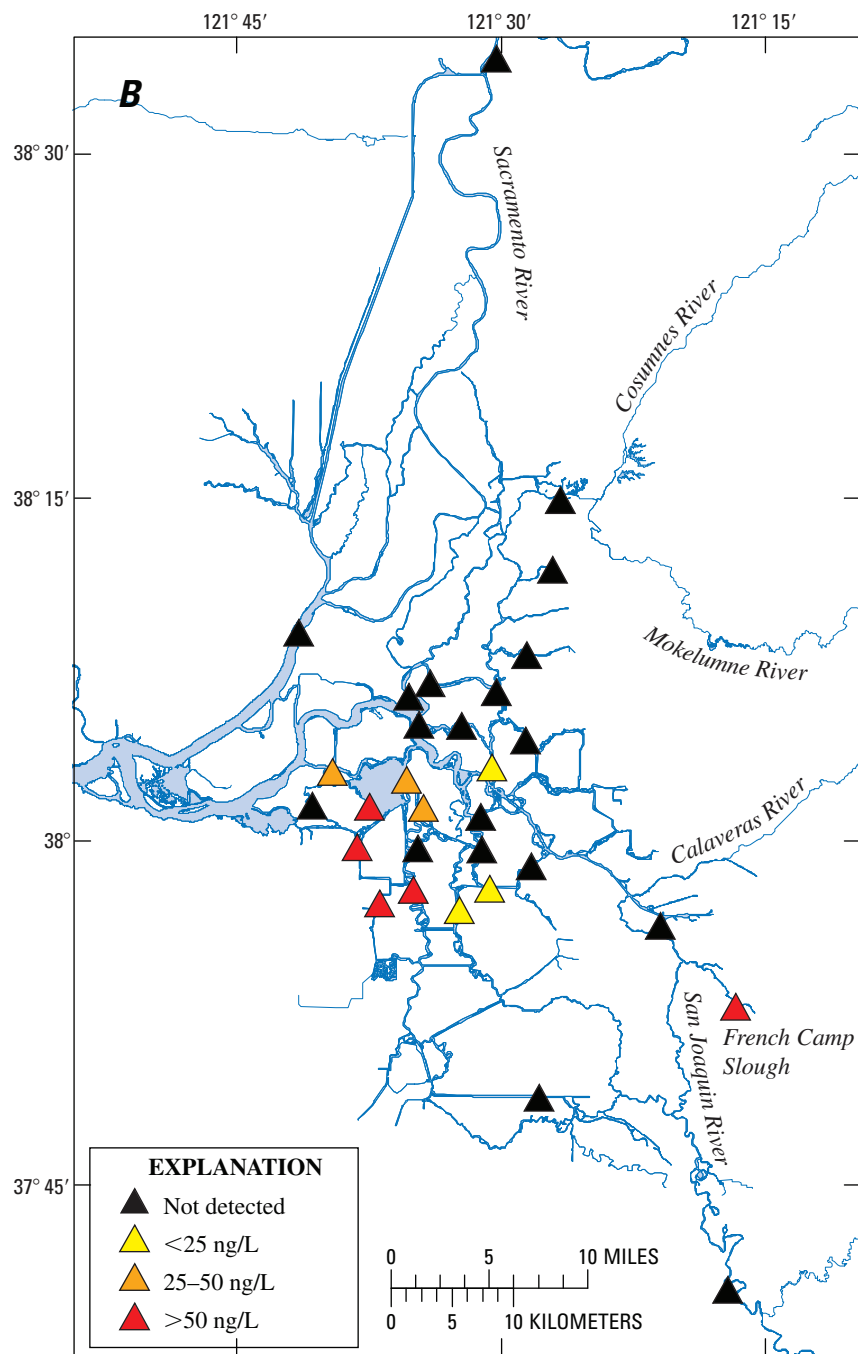


Figure 5B. Continued.

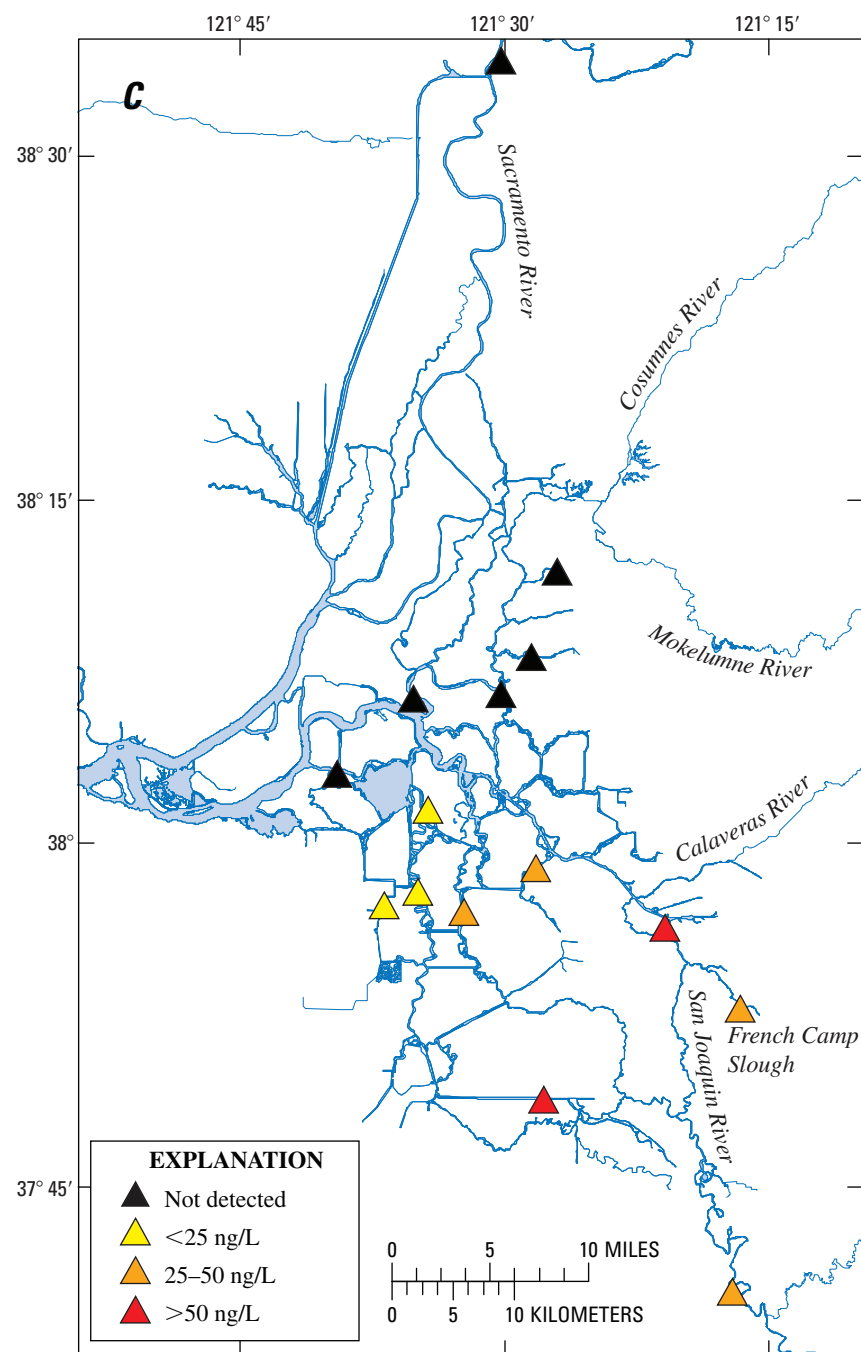


Figure 5C. Continued.

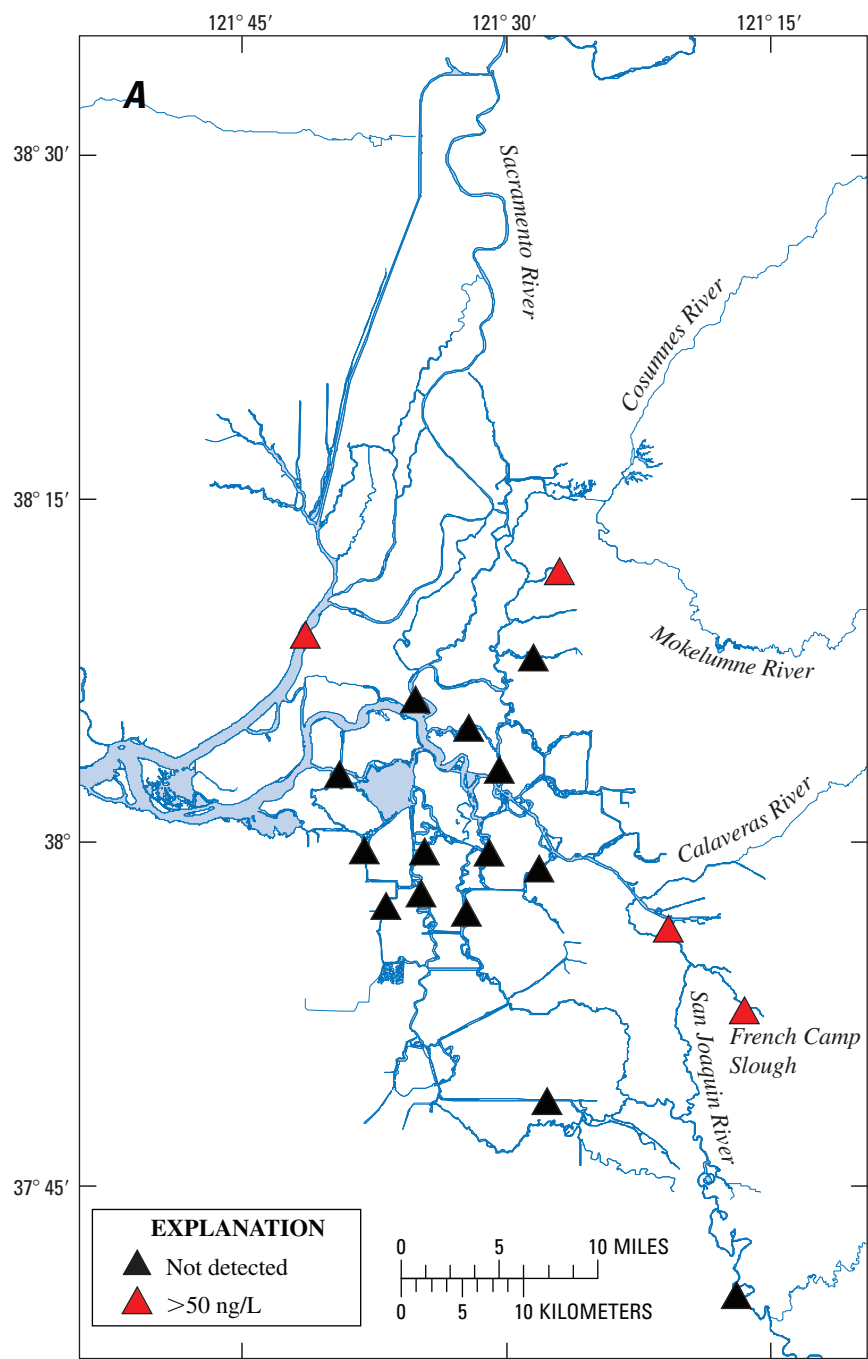


Figure 6. Molinate detections in the summer of 1994 (A), 1995 (B), and 1996 (C).

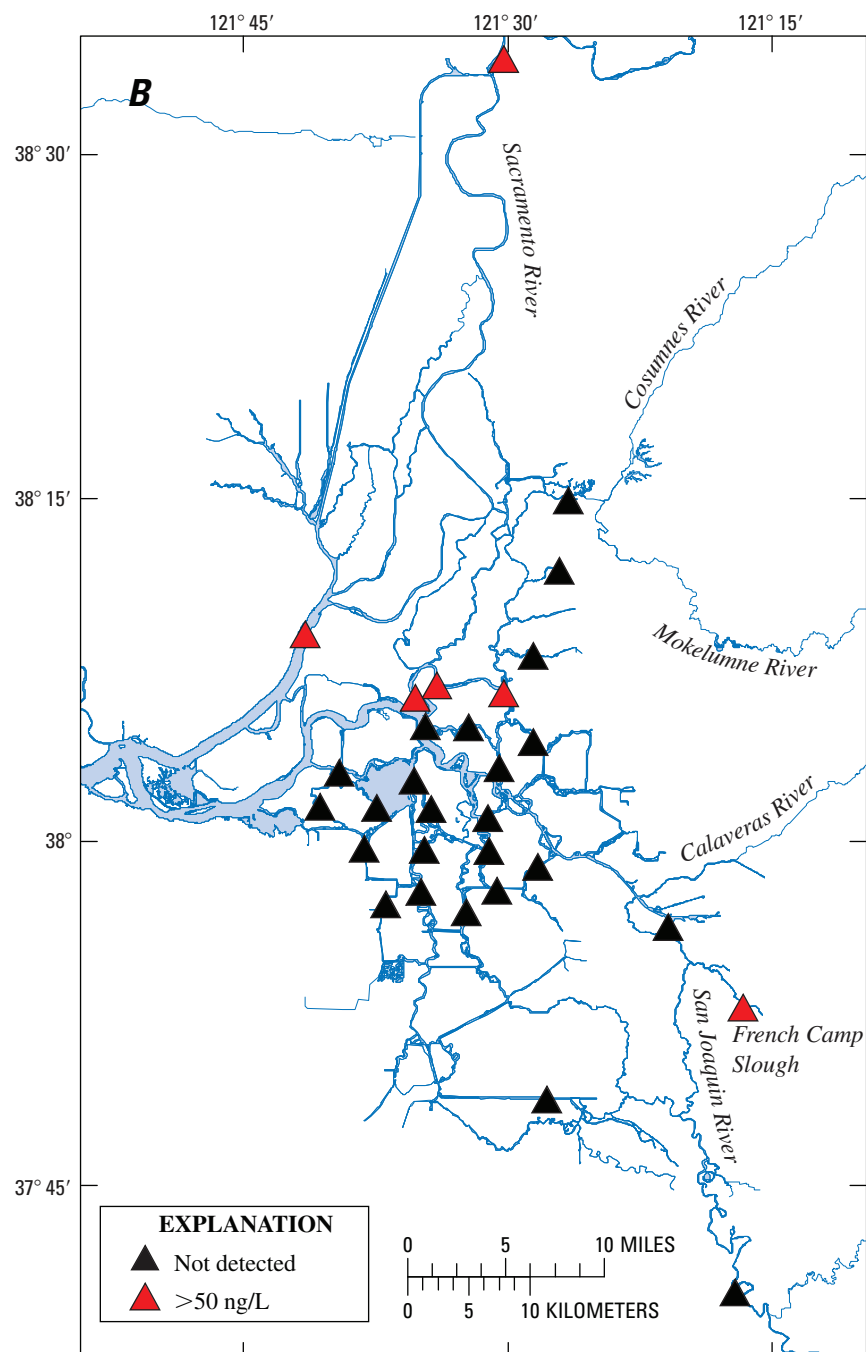


Figure 6B. Continued.

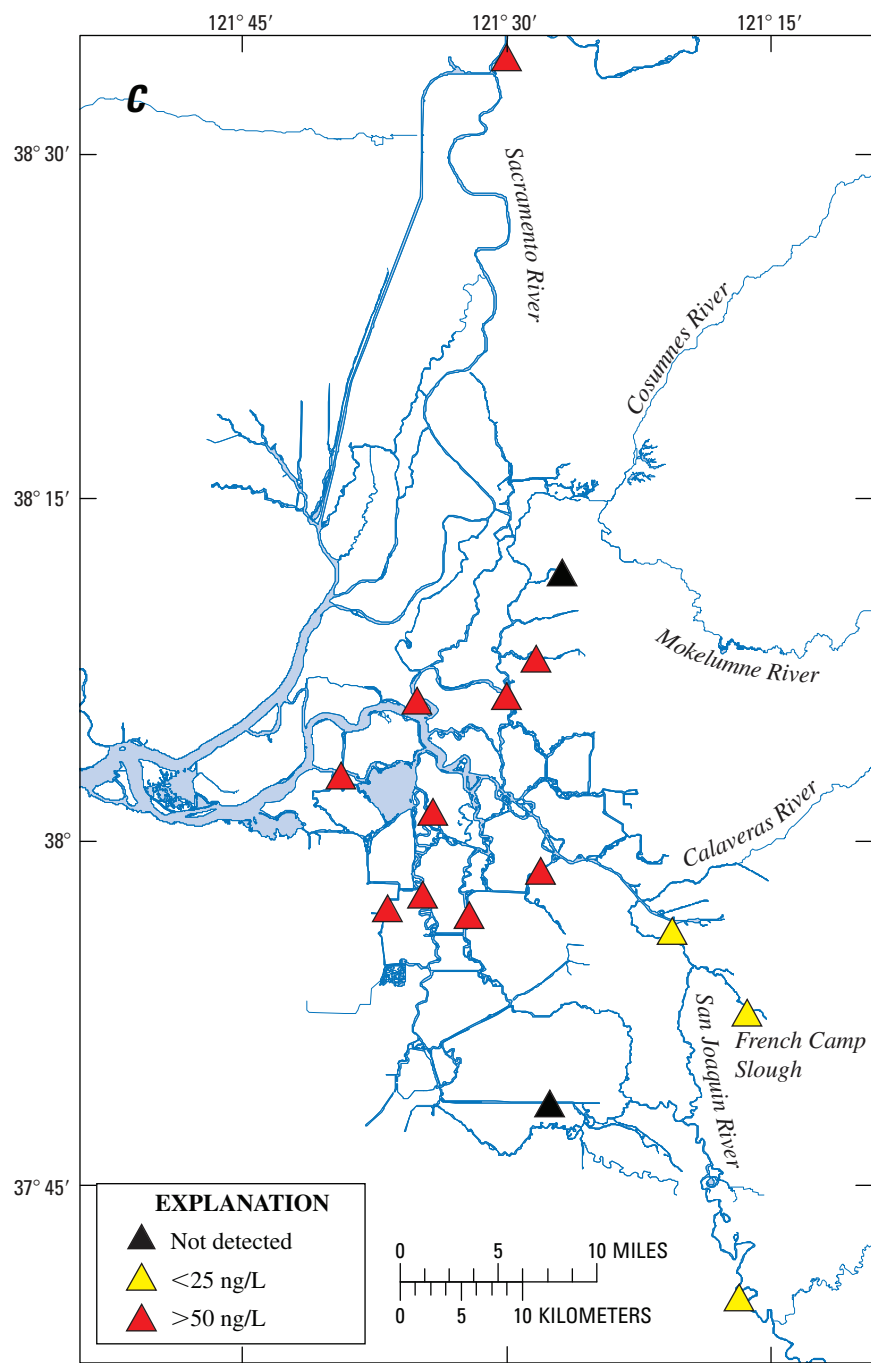


Figure 6C. Continued.

Overall, DOC concentrations ranged from 1.4 mg/L to 10.4 mg/L, and had a median concentration of 3.8 mg/L. On a seasonal basis, the lowest maximum DOC concentrations occurred in summer 1994 and winter 1994. The highest medi-

an concentration on a seasonal basis occurred in spring 1995 (fig. 7). The highest DOC concentrations were detected at French Camp Slough in two of the five seasons sampled (table 15).

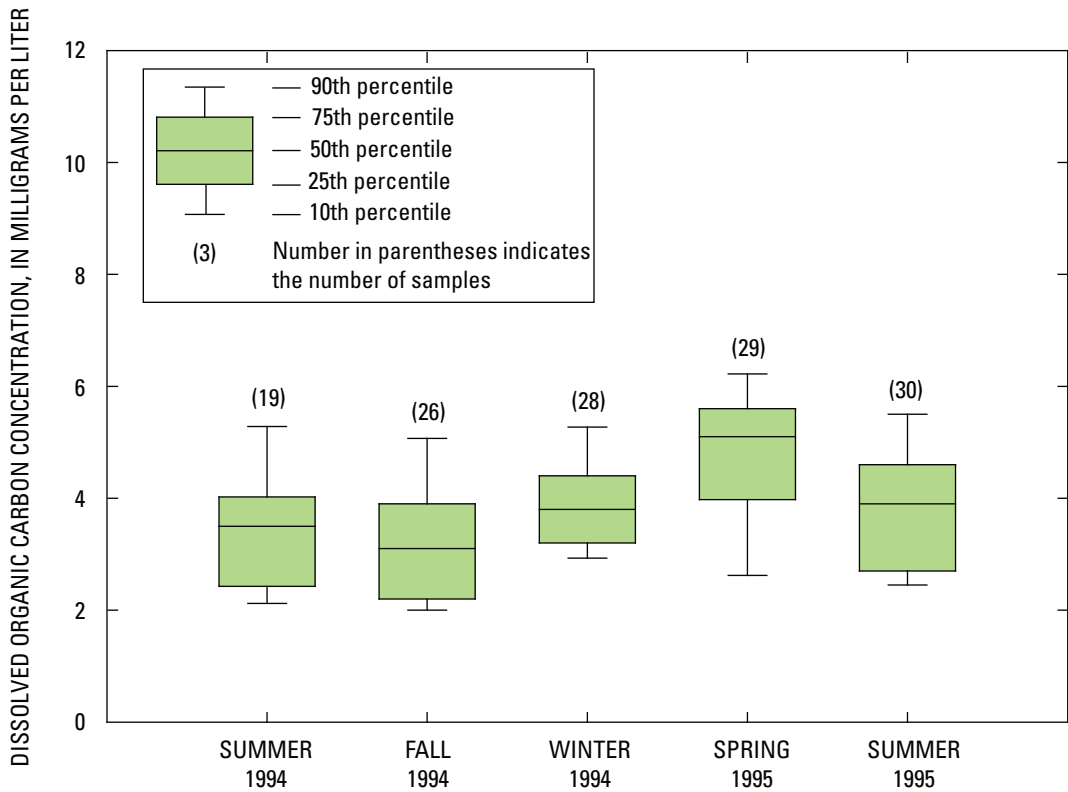


Figure 7. Box plots of dissolved organic carbon concentration by season.

Table 15. Seasonal range, median concentration, and location of highest dissolved organic carbon concentration, 1994–1996.

[Dissolved organic carbon was not analyzed in the summer 1996 season; mg/L, milligrams per liter; na, not analyzed]

	Range of dissolved organic carbon concentrations (mg/L)	Median dissolved organic carbon concentration (mg/L)	Location of highest dissolved organic carbon concentration	Site number
Summer 1994	1.8 to 8.8	3.5	Stockton	25
Fall 1994	1.5 to 10.3	3.1	French Camp	9
Winter 1994	2.5 to 6.7	3.8	Rio Vista	7
Spring 1995	1.4 to 10.4	5.1	Beaver Slough	2
Summer 1995	1.4 to 10.4	3.9	French Camp	9
Summer 1996	na	na	na	na

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